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Water Supply to Patna through River Bank Filtration: Problems and Prospects

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ABSTRACT: Patna, the capital of the State of Bihar in India, is situated on the bank of Ganga, a major perennial river, with a population currently of 1.7 million with an increasing trend. The source of water supply to Patna has exclusively been groundwater from confined aquifer extending from 100 m to 300 m extracted by a number of deep tubewells. On account of falling water levels in the tubewells, water supply to the city is getting stressed particularly during summer months. There may also be environmental hazard due to overexploitation. Hence augmentation of water supply to Patna from another source is a prime need. The obvious alternative of using the river water is presently ruled out primarily due to heavy recurring cost of treatment required. In this context, the technique of River Bank Filtration (RBF) seemed prospective. A two-year project on investigating the technical feasibility of RBF at Patna was carried out by Integrated Hydro Development Forum, Patna under European Cross Cultural Programme of European Union. The lithological investigations showed that the deep aquifer supplying water to Patna is connected to the river through a thick sand layer formation under the river bed. This connectivity is corroborated by simultaneous water level and water quality observations of the river and tubewells. Also, there are good aquifers at shallow depths in selected bands in Patna, representing abandoned courses of river Sone which are possibly potential sites of RBF on river Ganga. Further investigations including isotope studies and pilot projects are recommended to confirm connectivity of aquifers with the river and to establish techno-economics of RBF at Patna for augmenting it's stressed water supply

INTRODUCTION

Patna, the capital of the state of Bihar in India situated on the bank of river Ganga and having a population of 1.7 million has been getting its water supply almost exclusively from ground water through tubewells. A number of tubewells existing near or at short distances from the bank of the river supply water to a densely populated region stretching longitudinally along the bank in a length of 25 km with a width of about 5 km. These tubewells tap aquifers lying at depths varying form 100 m to 150 m overlain by thick clay layers. Although Ganga is a major perennial river flowing close to the town, it has not been considered as a source of water supply primarily for two reasons, (i) the cost of infrastructure for diversion of water as well as of its treatment necessarily required for drinking water use of polluted Ganga water, and (ii) then reliable and adequate source of ground water of good quality.

However due to expanding population of the town, water supply to Patna has been increasingly getting stressed due to lowering water levels in the tubewells and falling tubewell discharges, particularly during summer months. The need for augmenting water supply preferably from another viable source to the increasing population is being keenly realized in recent years. It is in this context that the technical feasibility of river bank filtration as a viable technique and strategy for the purpose was investigated through a two-year project carried out at Patna by Integrated Hydro Development Forum under Economic Cross Cultural Programme of the European Union.

EXISTING SITUATION OF WATER SUPPLY TO PATNA

Water supply to Patna is done exclusively from ground water by four different agencies, (i) Patna Water Board under Patna Municipal Corporation, (ii) Pubic Health Engineering Department of the Govt. of Bihar, (iii) Private housing cooperative societies and (iv) Individual house owners.

Out of these four agencies, Patna Water Board is by far the most major supplier of drinking water to the city residents. It presently operates a total of 85 tubewells, mostly of capacities varying from 60 to 120 hp

[1]Conference speaker

with an aggregate capacity of 7990 hp capable of discharging a total of 63,40,000 gallons per hour. These tubewells are operated for varying periods during the day, giving intermittent water supply to the residents. All of the 15 overhead water towers constructed by in the past have become defunct.

Public Health Engineering Department of the state government operates a total of 52 tubewells of capacities varying from 3 hp to 80 hp, with a total capacity of 14035 hp. It supplies water mostly to government offices and residential premises, and other government establishments such as hospitals and universities. Several of these tubewells are installed additionally with booster, jet or submersible pumps, with a total of 683.5 hp in order to improve the discharges.

Details of the pumps installed by the private housing cooperative societies and individual house owners are not available.

RELEVANCE AND PROSPECT OF RIVER BANK FILTRATION FOR WATER SUPPLY TO PATNA

The population of Patna, the premier city of the state of Bihar, the third most populous state in India, has been growing with increasing rates in recent years, necessitating increasing supply of drinking water. As ground water has exclusively been the only source to meet the drinking water needs, more and more ground water is being extracted from the deeper aquifers. As mentioned earlier, out of 85 deep tubewells under operation by the Patna Water Board, as many as 55 tubewells were installed between the years 2000 and 2004. Consequently, the deep aquifers containing water of acceptable drinking water quality are under stress. There is evidence that the annual withdrawal of water for drinking water purposes is exceeding the safe yield, resulting in falling water levels in the wells over the years. Moreover, during the summer when the demand for water is more, the water levels in the tubewells fall excessively, resulting in lesser discharges and more energy cost of extraction. Residents are subjected to stress in water supply annually during the summers. The impact is clearly visible among the low-income residents who depend on public water outlets provided by the Patna Municipal Corporation. Long lines of people at these outlets, resulting occasionally in scuffles and violent clashes, are common scenes in the city, particularly in the morning hours. Also, there may be environmental danger from overexploitation of ground water like its chemical contamination.

The city of Patna is therefore constrained to look for another suitable source of water to meet the growing demands for drinking water supply. The most obvious source is the river Ganga which is a major perennial river flowing close to the city. Although no serious thought has been given to using the surface water from the river on account of so far easy availability of ground water, identification of suitable off take point on the river, the initial cost of intake and conveyance structures and the recurring cost of treatment of water have been the inhibiting factors in considering the option with any seriousness.

It is in this context that the technique of Riverbank Filtration (RBF) held attraction and promise to address the emerging need of augmentation of water supply to Patna. In RBF, river water enters a tubewell situated near the bank of the river through filtration induced by pumping the tubewell. As the water passes through a pervious layer connecting the river and the aquifer being tapped by the tubewell, water withdrawn from the river under induced filtration undergoes a filtration process and gets purified by removal of pathogens and particulates (Ray, 2002). Thus, the discharge from such tubewells can be supplied for drinking water as it is, or after some low cost disinfection such as chlorination. This technique has been adopted for drinking water supply to several European cities situated on the banks of rivers and has been found adequate, reliable and cost effective (IITR 2004). The applicability, viability, sustainability and cost effectiveness of this technique has not been tried in India. Under the Economic Cross Cultural Programme between the European Union and India, a two-year collaborative programme among eight partners comprising 3 European institutions (University of Applied Sciences Dresden, Germany; University of Innsbruck, Austria; and University of East Anglia, U.K.), one European water company (Stadtwerke Dusseldorf, Germany), 2 Indian institutions (IIT, Roorkee and IT BHU), one Indian NGO (Integrated Hydro Development Forum, Patna) and one Indian water supply agency (Uttaranchal Jal Sansthan) for investigating applicability of RBF for three cities situated on the banks of the river Ganga, one at upstream Haridwar, the other in the lower middle reach at Varanasi and the third in the lower reach at Patna. The partner at Patna was Integrated Hydro Development Forum (IHDF), an incorporated non-profit technical professional organization. IHDF carried out the investigations during 2004–2006, the details of which are given below (IHDF 2006).

INVESTIGATIONS CARRIED OUT AT PATNA

Project Design

In the field visit to Patna for identification of a suitable tube well by a joint team of experts of the partner institutions, the site conditions were found to be unsuitable for installation of a monitoring well. Unsuitability was on account of the following factors:

1. the aquifers tapped by the existing tube wells were very deep, between 100 m to 300 m,
2. a clay layer of thickness up to 30 m (approx) covered the aquifers, and
3. the tube wells were pumped intermittently and not continuously.

Due to these conditions, filtration from the river to the tube wells was not expected. Therefore, it was decided to monitor the existing pumping tube wells for water level and water quality investigations instead of drilling a new monitoring well.

Accordingly, six pumping wells situated close to and along the riverbank and two additional pumping wells situated in the transverse direction along with one of the six wells were identified and selected for periodic monitoring of water levels and water quality. Additionally, three shallow open wells were identified and selected, two of which were located in the vicinity of selected tube wells along the river bank and one away from the bank in the vicinity of the farthest selected tube well in the transverse direction.

In order to monitor corresponding river water levels and river water quality, four sites on the river were identified and selected. All the 15 monitoring sites 8 tube wells, 3 open wells and 4 river sites are given in Table 1.

Table 1: Location Details of Monitoring Sites

Classification of Site		*G. L. Metres above Msl*	*Distance from River Bank Meters*	*Global Positioning*		*Location in Patna Town*
	Site Code			*Latitude*	*Longitude*	
River Ganga	R1	49.900	–	250 37.285′N	850 9.536′E	Near PMCH
	R2	50.572	–	250 37.264′N	850 10.596′E	Near Law College
	R3	49.577	–	250 37.182′N	850 10.951′E	Ghagha Ghat
	R4	47.545	–	250 36.697′N	850 12.429′E	Bhadra Ghat
Tube well	T1	53.980	10	250 37.315′N	850 9.912′E	In Cottage Ward of PMCH
	T2	53.535	70	250 37.277′N	850 9.649′E	In Tata Ward of PMCH
	T3	52.482	236	250 37.153′N	850 10.522′E	Near Law College
	T4	50.677	40	250 37.199′N	850 10.926′E	At Ghagha Ghat
	T5	54.265	100	250 36.702′N	850 12.247′E	In Gulzarbagh Field
	T6	55.770	92	250 36.579′N	850 12.436′E	In Govt. Press Premises at Gulzarbagh
	T7	48.347	1000	250 36.672′N	850 10.468′E	In Rampur Lane of Musallahpur
	T8	48.737	2000	250 26.02′N	850 11.215′E	Near Kumhrar Police Station
Open well	W1	51.952	342	250 37.096′N	850 10.370′E	Private well of Jagannath Mahto in Golakpur
	W2	53.822	191	250 37.072′N	850 10.904′E	Private well of Pradip Mahto near Ghagha Ghat
	W3	48.737	1950	250 36.037′N	850 11.184′E	Private well in Kumhrar, south of Patna-Mokama Rly. Line

Project Activities

Bench Marking of Sites

Reduced levels, i.e. levels with respect to the mean sea water level as datum were ascertained by carrying levels from a standard benchmark located in the campus of the nearby National Institute of Technology. These levels were marked by painting at a suitable spot at each of the 15 monitoring sites.

Observation of Levels

Surface water levels in the river were observed at all the four river sites, once a month during non-monsoon months, November to May '06, 3 times in June '06 and 4 times in July to October '06. Increase in frequency of observation of surface water levels was on account of rapid changes in water levels during monsoon months. Water surface levels in the river were measured by means of a leveling instrument and a staff gauge with reference to the reduced levels already marked or painted at the river site.

Ground water levels in the tube wells were observed with the same frequency and on the same dates as the river water levels. Measurement of the depth of water in the tube wells was done by means of a battery operated water depth measuring device consisting of a graduated electrical wire rolled round a spindle with a metallic piece at the end. While measuring the depth of water in the wells at least 2 hours after the pumping was stopped, this piece was lowered in the tube well pipe, keeping the device box at the concrete platform around the pump assembly. As soon as the metallic piece touched the water level, an electrical circuit in the device was closed, a bulb was lighted and a whistling sound was emitted alerting the operator that the water level in the well was just reached. The graduation on the electrical wire unrolled and lowered into the well gives the depth of water level in the well from the concrete platform which is converted into the reduced level of ground water level by means of the reduced level painted on the platform.

Ground water levels in the open wells were measured by means of the above-mentioned device with the same frequency and on the same dates as above. In the case of open wells, the device box was kept on the parapet of the open well.

Thus, water level measurements for the three water sources, i.e., river, tube wells and open wells, were made for all the 15 sites for 12 months, i.e., November 2005 to October 2006 at the frequencies mentioned above. In order to facilitate interpretation of water level data for the three water sources, 15 observation sites have been grouped into 6 clusters such that each of the first four clusters included one river site and the proximate tube well or tube wells and possibly an open well, the fifth cluster included one river site and the nearer of the two distant tube wells, and the sixth cluster included the same river site as in the fifth cluster, the farther of the two distant wells and the proximate open well. While the first four clusters are in the longitudinal direction, the last two are in the transverse direction to the river course. Accordingly, the six clusters into which all water level data have been grouped are as follows (the capital letter denoting source – R for river, T for tube well and W for open well and the number following it denotes site number):

Cluster 1 : R1, T1, T2
Cluster 2 : R2, T3, W1
Cluster 3 : R3, T4, W2
Cluster 4 : R4, T5, T6
Cluster 5 : R3, T7
Cluster 6 : R3, T8, W3

The water level data of the six clusters have been tabulated for each cluster. These data have been analyzed to give annual maximum, minimum and fluctuations in water levels in the three water bodies and also seasonal falls or rises in their water levels. These values have also been shown in the respective tables. For illustration, Table 2 gives the water level data and the analyzed values, as mentioned above.

Water Quality Investigations

Water quality investigations were also carried out for the three sources of water. For this purpose, water samples were collected once a month for 12 months, November 2005 to October 2006. The water samples from the river were collected with the help of a water sampler which was carried on a boat and dipped about 0.5 m below the water surface in the river about 150 m away from the bank. Water collected in the sampler container was poured in two bottles, one of which was sterilized in the laboratory for bacteriological test. Water samples for quality investigations were collected in two plastic bottles as mentioned above from tube wells from a water tap located at the pump house at least ½ hour after the pumping was started. Water samples from open wells were collected with the help of a bucket tied to one end of a rope, which was lowered into the well and the bucket was dipped about 0.5 m below the well water surface. The bucket was drawn up and poured into 2 bottles as mentioned above.

All the 30 water samples from 15 observation sites, two from each site, one put in an ordinary bottle and the other in a sterilized bottle, were taken to the Environmental Biology Laboratory of the Patna University for water quality testing. The samples were tested for the following water quality parameters:

Physico—Chemical Parameters: (i) Temperature, (ii) pH, (iii) Electrical Conductivity as an index of total dissolved solids, (iv) Total Alkalinity, (v) Total Hardness, (vi) Chloride, (vii) Sulphate and (viii) Dissolved Oxygen.

Bacteriological Parameter: Total Coliform

Apart from water quality testing for the above-mentioned parameters in the Environmental Biology Laboratory of Patna University, spot testing of the water samples for certain parameters such as Temperature, pH, Dissolved Oxygen and Conductivity was also done with the help of a Portable Water

Quality Kit as well as a hand-held device called Microprocessor Oxymeter. The results from spot testing were noted for reference. As these parameters were also measured in the Laboratory, only the laboratory results have been taken into account for further analysis and interpretation on account of their better reliability.

These results are shown in Table 3 for a non-monsoon month of Feb. '06 and in Table 4 for a monsoon month of Sept. '06 as an illustration.

Table 2: Water Level Data of Cluster 1 Sites

Location: Near PMCH

Month	*Observed Data*				*Analysed Data*			
	Surfacewater Level (m)	*Groundwater Level (m)*						
	River Gauge Site	*Nearby T/W Site*		*Nearby Well Site*	*Water Level/max Rise or Fall (m)*	*Remarks*		
	(R1)	*(T1)*	*(T2)*			*R1*	*T1*	*T2*
1	2	3	4	5	6	7	8	9
Nov. 05	43.254	40.390	40.810		Water Level (m)			
Dec. 05	41.970	40.270	40.430		(a) min RL	41.015 (Feb.)	38.57 (April)	38.55 (April)
Jan. 06	41.110	40.130	40.020		(b) max RL	48.78 (Sep)	44.44 (Sep)	44.42 (Sep)
Feb. 06	41.015	39.270	39.300		(c) Diff of max & min RL	7.765 m	5.87 m	5.87 m
Mar. 06	41.035	39.150	39.040					
April 06	41.130	38.570	38.550		Max Rise or Fall in water level(m)			
May 06	42.19	39.185	39.20		(a) During Non monsoon (Nov.–June)	2.239 (fall)	1.82 (fall)	2.26 (fall)
June 06	42.73	40.50	40.37		(b) During monsoon (June–Aug)	6.05 (rise)	3.94 (rise)	4.05 (rise)
July 06	46.49	42.60	42.57		(c) During period of observation (Nov.'05–Aug.'06)	7.765 (rise)	5.87 (rise)	5.87 (rise)
Augu. 06	48.445	43.84	43.22					
Sept. 06	48.78	44.44	44.42					
Oct. 06	44.715	43.01	42.96					

Table 3: Water Quality Testing Data for February 2006

Physico-chemical properties of water of the river Ganga, tube wells and open wells near river bank at Patna Month: February, 2006										
Sl. No.	*Sample Code*	*Water Temp.(°C)*	*pH*	*Elect.Cond. (uS/cm)*	*Total Alkalinity (mg/l)*	*Total Hardness (mg/l)*	*Chloride (mg/l)*	*Dissolved Oxygen (mg/l)*	*Sulphate (mg/l)*	*Total Coliform (MPN/100 ml)*
1.	R_1	27.5	8.1	465	160	240.57	16.67	8.46	16.47	30000
2.	R_2	27.2	8.1	441	162	248.68	16.67	8.38	16.80	50000
3.	R_3	27.5	8.0	455	164	270.03	17.71	7.82	17.90	50000
4.	R_4	27.6	7.9	462	164	237.86	17.19	7.01	17.35	90000
5.	T_1	27.8	7.7	505	234	313.55	29.70	6.69	3.95	50
6.	T_2	27.0	7.7	527	232	291.92	4.17	6.53	4.71	26
7.	T_3	28.1	7.4	552	238	294.63	7.82	4.11	5.04	50
8.	T_4	27.8	7.6	560	234	297.33	7.29	4.35	5.37	80
9.	T_5	27.9	7.6	556	232	324.36	8.86	5.24	9.55	70
10.	T_6	27.5	7.4	662	234	337.88	16.15	4.76	22.74	30
11.	T_7	27.5	7.7	565	224	354.09	20.84	2.50	8.56	50
12.	T_8	27.6	7.6	543	220	310.85	14.59	6.29	9.00	13
13.	W_1	28.2	7.4	1147	340	470.32	56.27	4.84	42.63	500
14.	W_2	28.0	7.5	1499	450	443.29	38.55	4.76	58.67	800
15.	W_3	26.5	7.4	923	338	362.20	55.23	3.39	21.20	1100

Table 4: Water Quality Testing Data for September 2006

Physico-Chemical Properties of Water of the River Ganga, Tube Wells and Open Wells Near River Bank at Patna Month: September, 2006										
Sl. No.	*Sample Code*	*Water Temp. (°C)*	*pH*	*Elect.Cond. (uS/cm)*	*Total Alkalinity (mg/l)*	*Total Hardness (mg/l)*	*Chloride (mg/l)*	*Dissolved Oxygen (mg/l)*	*Sulphate (mg/l)*	*Total Coliform (MPN/100 ml)*
1.	R_1	27.3	8.28	273	136	150	5.39	7.07	27.24	160000
2.	R_2	27.6	8.22	272	132	132	5.39	6.39	28.23	90000
3.	R_3	27.5	8.16	251	120	118	5.39	6.47	26.47	50000
4.	R_4	27.7	8.29	240	112	126	4.90	6.99	32.63	90000
5.	T_1	27.2	7.76	533	284	248	3.92	6.24	4.49	240
6.	T_2	27.4	7.79	527	120	242	2.94	6.47	5.15	130
7.	T_3	27.8	7.47	565	292	228	7.35	4.59	6.03	13
8.	T_4	27.8	7.50	550	280	274	5.39	4.74	4.60	30
9.	T_5	27.5	7.43	554	268	274	8.33	4.29	10.76	70
10.	T_6	27.2	7.42	650	292	290	15.19	6.24	26.91	240
11.	T_7	27.6	7.53	568	248	264	21.07	3.76	10.21	50
12.	T_8	27.2	7.64	538	260	260	14.70	5.87	9.88	500
13.	W_1	26.1	7.41	1111	400	346	54.88	4.29	50.32	1300
14.	W_2	26.0	7.33	1596	532	394	74.48	4.21	58.01	2400
15.	W_3	27.0	7.26	1232	484	526	101.92	4.96	43.29	3000

Results of Analysis of Observations

Water Level Observations

The observations were carried out from November 2005 to October 2006. Cluster wise analyzed data of water levels are given in Table 5.

Water quality investigations

The results of water quality testing for all the 15 sites for 12 months were analyzed for ranges of variations for each source of water for different quality parameters season-wise, i.e. for monsoon months as well as for non-monsoon months. Results from such analysis are given in Table 6.

Historical and Geological Investigation

Historical investigation

Evidence of old course of River Sone passing through and very close to Patna Town before 750 AD has been found in old records of the Archives of Bihar State, as mentioned in Bihar Govt. document (PWD 1966). These records mention that:

"The low land to the south of R. Ganga could have been abandoned course of Sone river. In the distant past, its probable course was through Chilbili, 3 km south of Phulwari station from which it pursued an easterly direction to Panch Pahari, 2 km south of Gulzarbagh station (Agamkuan) in Patna City and thence it followed a course roughly parallel to the river Ganga until it finally joined Ganga near Fatwa. The ground south of Patna in the last mentioned is low lying and destitute of tree and is still referred to as the "Mara Sone" which means the dead or deserted Sone and marks the bed of the old channel of the river. Borings that have been sunk in the area show coarse sand, typical of the Sone river. It has also been found in the tank near the Patna Secretariat, in Phulwarisharif area and further westward in the vicinity of Maner. An old Patliputra map suggests that in the earlier centuries of Christian era the Sone gradually worked westward as far as Phulwari about 5 km. south of river Ganga at Patna, and it is probable that it broke through the narrow neck of land dividing it here from the Ganga before the year 750 A.D. During the subsequent centuries, the river has continued its westward movement, forming new channels for itself, one of them being the present alignment of the Patna canal. Later, in its westward progression it entered the Ganga river at Sherpur, 10 km east of Maner and afterwards, as today, at Maner itself. In Rennel's Survey of 1779, the river Sone is shown as entering the parent stream at Maner, but it is not known how long before that the westward swing of the river had been completed.

All the same, availability of coarse sand typical of river Sone in the areas around Patna Secretariat, Phulwarisharif and further westward in the vicinity of Maner makes them potential sites for RBF on river Sone near Patna. Recent lithological investigations also confirm availability of coarse sand just 2 m below ground level in a depth of 12 m and again between 20–75 m depths.

Table 5: Clusterwise Analyzed Water Level Data

Cluster No.	*Site Identification*	*Difference of Maxm & Minm Water Levels (M)*		
		During Non-Monsoon	*During Monsoon*	*During the Period of Observation*
1.	R1	2.239 (Fall)	6.05 (Rise)	7.765 (Rise)
	T1	1.82 (Fall)	3.94 (Rise)	5.87 (Rise)
	T2	2.26 (Fall)	4.05 (Rise)	5.87 (Rise)
2.	R2	3.278 (Fall)	6.02 (Rise)	7.69 (Rise)
	T2	1.543 (Fall)	3.47 (Rise)	5.33 (Rise)
	W1	0.945 (Fall)	0.98 (Rise)	2.275 (Rise)
3.	R3	2.143 (Fall)	5.773 (Rise)	7.643 (Rise)
	T4	2.070 (Fall)	4.02 (Rise)	5.75 (Rise)
	W2	0.925 (Fall)	1.59 (Rise)	2.515 (Rise)
4.	R4	2.160 (Fall)	5.709 (Rise)	7.649 (Rise)
	T5	1.249 (Fall)	3.99 (Rise)	5.964 (Rise)
	T6	2.100 (Fall)	3.62 (Rise)	5.87 (Rise)
5.	R3	2.143 (Fall)	5.813 (Rise)	7.643 (Rise)
	T7	1.950 (Fall)	3.63 (Rise)	5.56 (Rise)
6.	R3	2.143 (Fall)	5.813 (Rise)	7.643 (Rise)
	T8	3.093 (Fall)	5.310 (Rise)	7.00 (Rise)
	W3	1.280 (Fall)	0.90 (Rise)	1.86 (Rise)

Table 6: Ranges of Variation of Water Quality

Range of Test Result Values (Max-Min) of Different Parameters of Water Quality Testing from River, Tubewells and Open Wells Monitoring Sites										
Source of Water (River/TW/OW)	*Parameters of Water Quality Testing*									
Desirable Limit for Drinking Water (as per Indian Standards IS:10500-1983/ IS:2296-1982)	*Temp (oc) (Min-Max)*	*ph-Value (Min-Max)*	*Elect. Cond. (uS/Cm) (Min-Max)*	*Total Alkalinity (mg/l) (Min-Max)*	*Total Hardness (mg/l) (Min-Max)*	*Chloride (mg/l) (Min-Max)*	*Disolved Oxygen (mg/l) (Min-Max)*	*Sulphate (mg/l) (Min-Max)*	*Total Coliform (MPN/100 ml) (Min-Max)*	*Remarks*
	N.A.	*5.6–8.5*	*–*	*N.A.*	*300 (Max)*	*250 (Max)*	*6 (Min)*	*150 (Max)*	*50 (Max)*	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
River										
(a) During Non- Monsoon Months	18–33.6	7.8–8.44	303–549	110–230	104.56–505.6	11.66–20.58	4.79–9.06	12.19–28.67	24000–160000	
(b) During Monsoon Months	29.4–30.7	7.84–8.21	220–296	84–284	90–122.74	3.54– 9.14	3.54–5.61	9.11–41.53	90000–160000	
T/W										
(a) During Non- Monsoon Months	18–29	7.1–7.8	505–681	212–290	84.1– 363.92	3.06– 68.85	2.4–7.37	2.3–30.76	8–170	
(b) During Monsoon Months	28.3–28.7	7.51–7.87	219–940	236–284	142– 218.21	3.37– 41.37	4.17–6.62	2.96–73.95	8–300	
Open well										
(a) During Non- Monsoon Months	18.1–28.3	7.0–8.0	923–1547	272–522	147.75–502.74	38.55– 82.5	1.78–6.87	18.01–57.24	170–2200	
(b) During Monsoon Months	28–28.5	7.43–7.65	210–1532	374–536	356– 445.51	51.96–113.52	3.49–5.53	29.22–60.32	800–5000	

Records of tube well borings in the Patna town passing through the under noted locations show that water bearing strata (coarse sand of fineness modulus 2.6) is available just 2.0 m below ground level, its thickness being approximately 12.0 m and again between 20–75 m depths. Fineness Modulus (F.M.) of sand in the bed of river Sone at 'Maner'/'Kolewar' is also of the same value i.e., 2.6. Hence some sort of connectivity between the two strata of coarse sand may be expected subject to confirmation by further investigations.

All the same, availability of coarse sand typical of river Sone in the areas around Patna Secretariat, Phulwarisharif and further westward in the vicinity of Maner makes them potential sites for RBF on river Sone near Patna. Recent lithological investigations also confirm availability of coarse sand just 2 m below ground level in a depth of 12 m and again between 20–75 m depths.

Records of tube well borings in the Patna town passing through the under noted locations show that water bearing strata (coarse sand of fineness modulus 2.6) is available just 2.0 m below ground level, its thickness being approximately 12.0 m and again between 20–75 m depths. Fineness Modulus (F.M.) of sand in the bed of river Sone at 'Maner'/'Kolewar' is also of the same value i.e., 2.6.

Hence some sort of connectivity between the two strata of coarse sand may be expected subject to confirmation by further investigations.

Location of areas in Patna having traces of old course of R. Sone are the following:

1. Bihar Veterinary College
2. Biological Garden
3. Patna Secretariat
4. Patliputra Hotel
5. Patna Museum
6. Police Line (Lodipur)

A representative lithological log chart of the above areas based on tube well borings is given in Figure 1. Availability of coarse Sone sand so close to the ground level i.e., below 2.0 m depth of clay in all the above locations (unlike 60.0 m depth of clay on Ganga bank at Patna) has potential to prove suitable for river bank filtration at shallower depths along the old course of river Sone in Patna town.

Lithological investigation

In order to achieve the objective of the study, apart from water level and water quality investigations for the three sources of water, some lithological investigations of the concerned area were also carried out. For this purpose, lithological log charts of various tube wells as well as exploratory boreholes in the study region were obtained from various agencies such as PHED, PWB, CGWB and GSI. These log charts have been redrawn on a common vertical scale and shown in Figure 2.

In addition to these log charts, three log charts in the cross-sectional width of the river have been procured from the Public Works Department of the Govt. of Bihar, which were obtained by them in course of the site investigations for a bridge across Ganga at Patna. These log charts along with the log charts of three of our selected tube wells, T3, T7 and T8 which are in the same line, have been redrawn on a common vertical scale and shown in Figure 3. Thus, Figure 2 and Figure 3 indicate the lithology of Patna along the bank of the river Ganga and across it, respectively.

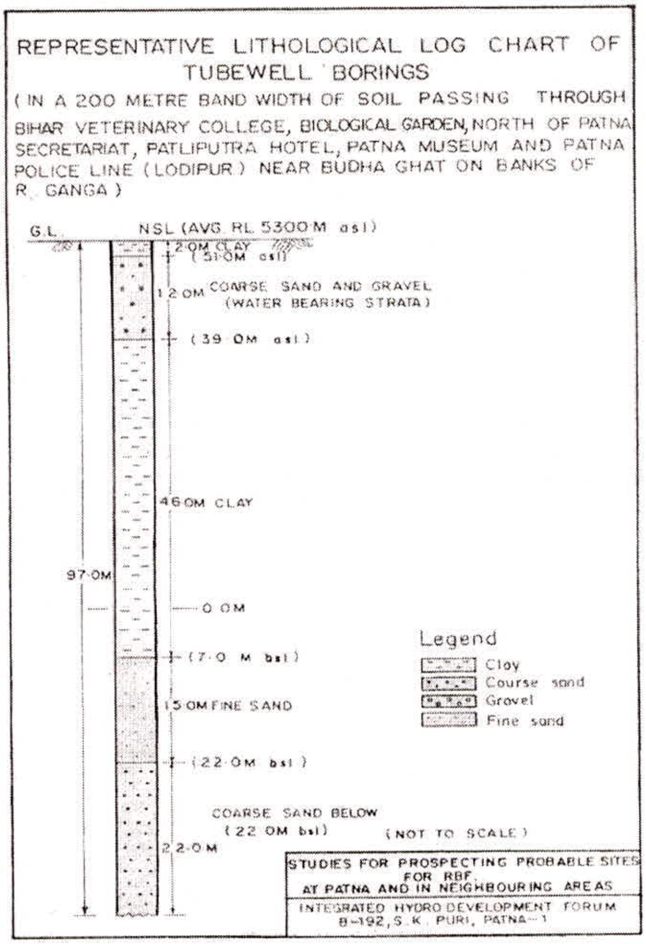

Fig. 1: A Representative Log Chart of Band indicating Old Sone Course

Analysis and Interpretation

Lithological investigations indicate that while the first layer of aquifer exists between 15 m and 30 m above msl, the second layer exists in a large thickness between 0 m and 148 m below msl. At the same time, the strata below the river bed consists of sand of varying fineness modulus in large thickness of 180 m, interspersed with thin layers of silt and sand stones.

This lithological feature indicates that the aquifer being tapped for water supply to Patna is connected to the sandy layer of large thickness below the riverbed. This interconnectivity is further corroborated by water level and water quality investigations. While seasonal fluctuations of water levels in the river were of the order of 7 m, those in the tubewells were of the order of 5 m. While water levels in the river were invariably higher than those in the tubewells, they were lower than those in the open wells. Trends of rise and fall of water levels in the river invariably corresponded with those in the tube wells.

The physico-chemical parameters of water quality of both the rivers and the tube wells were of similar orders of magnitude in both monsoon and non-monsoon seasons. Much higher levels of bacteriological parameter in the river, total coliform, were understandably on account of pollution loads being discharged into the river.

Thus, the connectivity of the sandy layer below the river bed with the aquifer below the banks at deeper layers indicates a promise of river bank filtration in the stretch of river Ganga investigated in this project

At confluence locations of certain abandoned courses of river Sone with river Ganga at Patna, coarse sand aquifers exist at low depths of about 2 m. These locations on the bank of river Ganga at Patna have good prospect of river bank filtration.

The particular band width of Patna town (200 m wide) passing through Bihar Veterinary College, Biological Garden, Patna Secretariat, Patliputra Hotel, Patna Museum and Police Line (Lodipur) comprises soil having good permeable strata between 2–14 m and 60–75 m depth and extends to the banks of river Ganga near "Buddha Ghat". This 'band width' of Patna is said to be seated on an old course of river Sone, which is also corroborated by log chart of soil showing availability of coarse sand (FM = 2.6) typical of Sone river. Hence this band of Patna having traces of old course of river Sone has a potential for locating further RBF sites on the banks of river Ganga

CONCLUSION AND OUTLOOK

From the investigations done, analysis carried out and logical interpretations made, as indicated above, it can be tentatively concluded that RBF offers a viable option for augmenting water supply to Patna. In order to conform this tentative conclusion, the following further investigations and follow up projects need be launched:

1. Investigations by isotopic studies and through exploratory boreholes may be done to conclusively confirm connectivity of river bank and river bed aquifers.
2. Two pilot projects, one for the deeper river bank aquifer and the other for shallow river bank aquifer at the abandoned confluence point may be launched for studying the techno-economics of RBF for water supply to Patna from river Ganga.

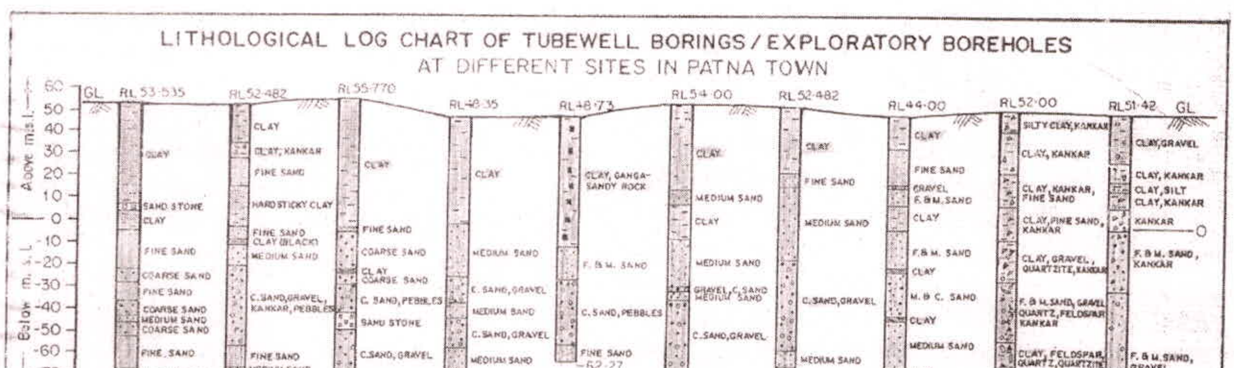

Fig. 2: Lithological Log chart of Tube well/Bore Holes Longitudinal to River Bank

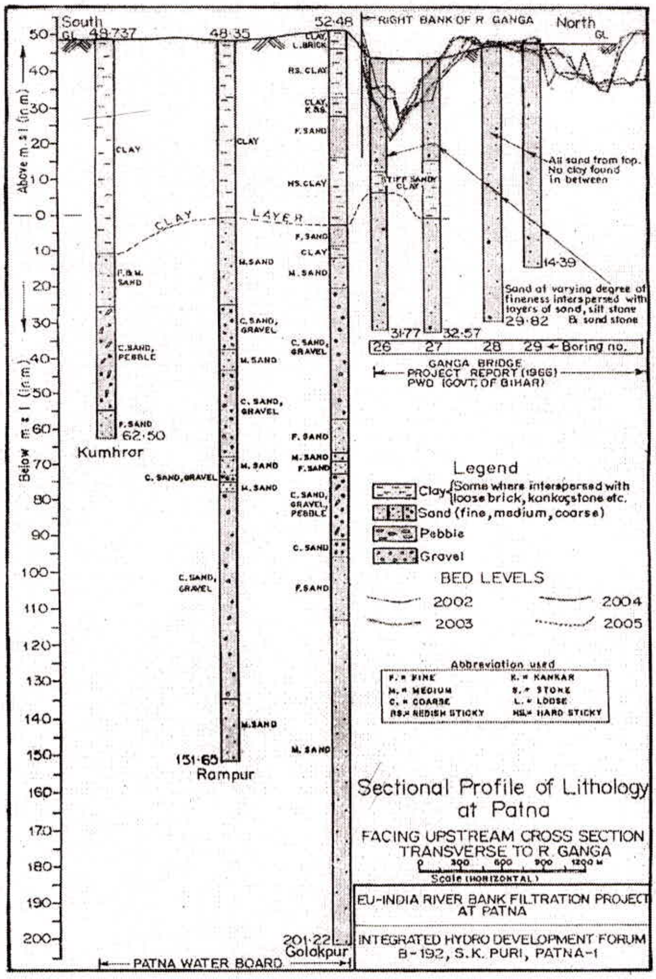

Fig. 3: Lithological Log chart of Tube wells/Bore Holes Transverse to River Bank

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